

## 25. Rainwater Harvesting (RWH)

**Description**

**Rainwater harvesting (RWH)** is a method by which rainwater that falls upon a surface (usually a rooftop) is collected and routed to a storage facility for later use. To achieve runoff reduction credit, RWH systems must include not only the cistern (and needed components such as filters and perhaps a pump), but also a reliable means of using or releasing the captured rainwater.



**Siting & Use**

- Yes High SHWT
- Yes Tight soils
- Yes Very steep sites
- Yes Highly impervious sites
- Yes Pathogen removal
- Yes Temperature control

**Design Objective**

A RWH system shall be designed to capture and use or disperse a minimum of 86% of the total annual runoff from its catchment as demonstrated through water balance equations. NCSU’s Rainwater Harvester Model or another computation method must be used to confirm that the cistern sizing and proposed use of the rainwater will meet the design objective.

Stormwater Credits	
Runoff Reduction	100% reduction of the runoff volume from the design storm .
TSS removal	85% reduction of the annual Total Suspended Solids (TSS) mass load.
Nutrient removal	35% reduction of the annual Total Nitrogen (TN) mass load. 45% reduction of the annual Total Phosphorus (TP) mass load.
BUA Status	For the purpose of high/low density calculations, the footprint of the roof or paved catchment area shall be considered impervious and the footprint of the vegetated receiving area shall be considered pervious.

Photo depicts a rainwater harvesting system at the Craven County Agricultural Center that was designed and monitored by NC State University Department of Biological and Agricultural Engineering (photo courtesy of NCSU-BAE).

**Major Design Elements:**

The two tables below list major design elements falling into two categories:

- Required Design Elements
  - These requirements must be addressed to receive regulatory credit without submitting additional information.
  - Meeting these requirements leads to a smooth, straightforward review.
  - These requirements only address stormwater criteria. There are other crucial aspects of design, but only those related to stormwater credit are listed.
  - Throughout this chapter the terminology “shall” will be used to refer to these elements.
- Recommended Design Elements
  - These items are not required to receive regulatory credit but represent good design practice and lead to optimum performance.
  - The designer will determine if these elements should be included in the design.
  - Throughout this chapter, the terminology “should” will be used refer to these elements.
  - Elsewhere in this chapter, other elements will be introduced using the terminology such as “may” to refer to options.

Design professionals desiring to deviate from this chapter shall provide technical justification that their design is equally or more protective of water quality (vague, anecdotal or isolated evidence is not acceptable). Review staff shall consider deviations from the required items in this chapter on a case-by-case basis. Alternative designs may receive lower regulatory credits.

**Table 25-1. Major Design Elements**

1.	A NC licensed professional with appropriate expertise shall design RWH systems that seek stormwater credits.
2.	All RWH systems shall comply with applicable state and local regulations and codes, including, but not limited to the North Carolina Building Code and the North Carolina Administrative Code. For systems with a potable water back-up, cross-connection control requirements will apply.
3.	The cistern shall be sized to capture a minimum of 86% of the total runoff as demonstrated through water balance calculations. The captured runoff in the cistern shall be either (a) used to meet a non-potable water demand or (b) discharged via a passive drawdown device to a vegetated infiltration area meeting the requirement of this chapter (if allowed) or to a stormwater BMP sized per another chapter of this manual.
4.	The non-potable water demand must be quantified and the calculations shall be included in the design documentation.

5.	The water balance shall be calculated using the NCSU Rainwater Harvester model or another continuous-simulation hydrologic model that calculates the water balance on a daily or more frequent time-step using a minimum of 5 representative years of actual rainfall records. The model shall account for withdrawals from the cistern for usage and for the active or passive drawdown as well as additions to the cistern by rainfall and runoff and by a make-up water source (if applicable).
6.	If a back-up water supply discharges into the cistern, this water volume shall be accounted for in the design.
7.	RWH systems shall include a functioning distribution system prior to being considered complete. The design of this system shall include testing protocols which shall be executed in the prior to acceptance of the system at construction completion.
8.	A pre-treatment device shall be included upstream of the cistern to minimize gross and course solids collection in the tank.
9.	Cisterns shall be constructed to prevent light from entering the cistern.
10.	Safety measures appropriate to the cistern type shall be installed to address issues such as fall protection and confined spaces. Safety measures shall comply with federal and state occupational safety regulations.
11.	All manufacturer requirements, product standards, and industry guidelines shall be followed to ensure lasting effectiveness (in addition to meeting the requirements of this chapter).
12.	All harvested rainwater outlets (e.g. spigots, hose bibs), storage facilities, and appurtenances shall be labeled as “Non-Potable Water” to warn the public and others that the water is not intended for drinking.
13.	RWH systems shall be designed to provide safe, non-erosive conveyance of the 10-year, 24-hour storm event via infiltration, bypass or detention and release.
14.	Passive drawdown devices, when employed, shall be designed to prevent clogging.
15.	Passive drawdown devices, when employed, shall be marked with identifying signage or labels that is visible to owners and maintenance personnel.
16.	Interior distribution piping for harvested rainwater shall comply with the NC Plumbing Code.
17.	RWH systems shall be inspected and maintained as specified in Section 25.6.
18.	<u>Recommended:</u> An indicator of water level should be visible to users and maintenance personnel.
19.	<u>Recommended:</u> All spigots, hose bibs or other outlets for the harvested rainwater should be of a type, or secured in a manner, that permits operation only by authorized personnel, such as a locked below grade vault or a spigot that can only be operated by a tool.
20.	<u>Recommended:</u> Exterior distribution piping for the harvested rainwater should be color-coded, taped, or otherwise marked to identify the source of the water as non-potable.

## 25.1. Description and Purpose



Figure 25-1. Typical RWH System (NCSU-BAE)

Rainwater harvesting (RWH) systems include many components that work together to collect, store, and use rainwater.

Two primary objectives drive design of RWH systems:

- To manage stormwater through mechanisms of runoff volume reduction, peak discharge detention, and water quality treatment. This can reduce the need for BMPs elsewhere on the site.
- To conserve potable water by developing an alternate non-potable water supply. This can reduce the cost of operating the site.

Stormwater management and water conservation are sometimes opposing goals, requiring designers and operators to make trade-offs. For example, a full cistern is ideal for water conservation objectives (providing water when it is needed), but a full cistern cannot provide the stormwater management benefit of detention. Possible benefits related to each goal are listed in the table below. Systems optimized for one objective can achieve some of the benefits of the other objective.

Note that this chapter focuses on RWH systems for stormwater treatment, specifically for regulatory credit in North Carolina. Those interested in RWH systems for solely water conservation or water supply purposes may be better served by other design standards.

Required components of a RWH are listed in Table 25-2 below. Optional components of an RWH include:

- **Water level indicator** – This is especially useful for actively managed systems.
- **Secondary water supply** – An automated secondary water supply may be provided to supplement the rainwater captured.
- **Post-storage (point-of-use) treatment** - Post-storage treatment is sometimes included, depending upon the quality of water in the storage tank and the quality needed for the designated non-potable water uses.
- **Usage meter** – Meters on the distribution system may be required by local jurisdictions. They may also be desired by owners of larger-scale systems who wish to monitor their water use.

**Table 25-2. Required Components of an RWH**

<b>Catchment surface</b>	Usually the catchment surface is a rooftop; however, collecting runoff from other surfaces, such as parking lots, sidewalks and landscaped areas is allowed. The lower quality of runoff leaving these surfaces may require greater treatment than runoff from roof surfaces.
<b>Collection System</b>	When the catchment surface is a rooftop, the runoff is collected via gutters then conveyed to the cistern by downspouts. For stormwater harvesting systems, a storm drainage system may be involved.
<b>Pre-cistern filtration</b>	Pre-cistern filtration prevents sediment, leaves and debris from entering the cistern. It includes screens, gutter screens and filters, and first flush diverters. For stormwater harvesting systems, this function may be achieved with settling tanks, oil-grit separators, hydrodynamic separators, sand filters, or proprietary devices.
<b>Cistern</b>	The cistern is the above-ground or underground storage vessel that holds the rainwater until it is used. This is also called a rainwater tank.
<b>Overflow</b>	The overflow allows rainfall in excess of the designed storage volume of the cistern to discharge.
<b>Passive or active drawdown</b>	The drawdown drains the cistern between rainstorms so that cistern capacity is available for stormwater treatment. A drawdown is required on nearly all RWH systems that receive stormwater credit. For single family homes, all RWH systems are anticipated to have a passive drawdown.
<b>Filtration or infiltration downstream of passive drawdown</b>	RWH systems using the passive drawdown – including nearly all single family homes – require filtration or infiltration downstream of the drawdown. The filtration or infiltration function shall be designed in accordance with this chapter of this manual.
<b>Non-potable water use (if passive drawdown not included)</b>	RWH systems are required to have a non-potable water use. Typical uses include irrigation, toilet flushing, and vehicle washing. Less common uses include cooling tower make-up, street sweeping tank filling, laundry, flushing animal waste systems, washing kennels, etc.
<b>Distribution system</b>	From the cistern, the water either drains via gravity or is pumped to the point of use.
<b>Signage</b>	Signage is required to indicate that the cistern water is not potable as well as to indicate that the “dripping” from a passive drawdown system is a part of the design and not a defect.

## 25.2. Regulatory Credit

RWH systems contribute to the stormwater treatment requirements of a site in the following ways:

- RWH Systems with dedicated non-potable water uses reduce the runoff volume and thereby reducing the size of other water quality treatment on site.
- RWH Systems on one- and two-family homes can include a passive drawdown that discharges to a filtration or infiltration device designed per this chapter. This will reduce the size of other water quality treatment on site.
- RWH Systems provide volume reduction and detention and can reduce the size of stormwater BMPs designed to meet runoff reduction and pollutant removal requirements.

RWH systems shall receive the following credits if sited, designed, constructed and maintained in accordance with this chapter. These credits are based on research conducted by NCSU's Department of Biological and Agricultural Engineering. Please note the credit applies to the entire system with all of its components, including a correctly designed collection system, anti-clogging device, cistern material and capacity, and year-round dedicated use and/or passive drawdown system with all the appurtenances necessary for correct function.

The correct match between the volume of the cistern and the dedicated use or passive drawdown device shall be verified by NCSU's Rainwater Harvester Model or other calculation method. The credits listed below are based on a RWH system that is designed to capture and use or disperse a minimum of 86% of the total annual runoff from its catchment as demonstrated through water balance equations.

The credits awarded to a correctly designed RWH system are:

- 100% reduction of the runoff volume from the design storm.
- 85% reduction of the annual Total Suspended Solids (TSS) mass load.
- 35% reduction of the annual Total Nitrogen (TN) mass load.
- 45% reduction of the annual Total Phosphorus (TP) mass load.

For the purpose of high/low density calculations, the footprint of the roof or paved catchment area shall be considered impervious and the footprint of the vegetated receiving area shall be considered pervious.

### 25.3. Siting and Feasibility

There are many considerations when determining if and how RWH systems should be used at a specific site. These are listed in Table 25-3 below.

**Table 25-3. RWH Siting and Feasibility Considerations**

<b>Installation Size</b>	There is no required minimum or maximum size for a RWH installation. However, small installations – such as rain barrels – may result in very little regulatory credit.
<b>Buffers and setbacks</b>	The infiltration or filtration area downstream of a passive drawdown may be allowed within Zone 2 of protected riparian buffers or the setbacks required under Phase II, Water Supply Watershed, Coastal Counties, HQW, ORW or other stormwater programs.
<b>Proximity to building foundations &amp; utilities</b>	The designer shall consider the loading of the full cistern and the proximity to foundations, utilities, or other infrastructure. For infiltration downstream of a passive drawdown, the designer shall consider the impact of infiltration on building foundations and utilities.
<b>Proximity to water supply wells</b>	For infiltration designs, there shall be a 100 ft setback from water supply wells. This distance may be reduced on a case-by-case basis if the design professional can justify to the permitting authority that the groundwater will be protected from stormwater pollution.
<b>Status of the site as high or low density</b>	RWH can be used on either high or low density sites.
<b>Soil type</b>	RWH systems may be used on any soil type, although soil conditions will dictate the design of infiltration areas downstream of a passive drawdown.
<b>Site slopes</b>	RWH systems may be used on sites with any slope. However, the design of filtration/infiltration downstream of a passive drawdown will vary based on the site slope.
<b>Seasonal high water table</b>	Seasonal high water table (SHWT) elevations will influence the design of underground cisterns. Also, the SHWT elevation will impact the design of some types of filtration/infiltration areas downstream of a passive drawdown. The SHWT elevation will generally not be a concern at above-ground installations on single family houses.
<b>Stormwater hotspots</b>	RWH may be used at stormwater hotspots if the catchment area to the cistern does not include hotspots. For example, the roof of a maintenance building could be the catchment area to a cistern. The maintenance yard should not be directed to a cistern due to water quality concerns.

<b>Redevelopment sites</b>	RWH may be used at redevelopment sites. However, the design options will be limited because stormwater shall not be infiltrated into contaminated soils because this can cause dispersion of toxic substances to other sites and to groundwater. If contaminated soils are present or suspected, the state recommends that the designer consult with an appropriately licensed NC professional. Also, homeowner’s Association covenants and local zoning ordinances may dictate setbacks and aesthetics that apply to RWH systems.
<b>Maintenance access</b>	Each element of the RWH system must be accessible for maintenance. Certain components must be accessible to the owner or site personnel on a daily basis.
<b>Operation</b>	RWH systems require more operational effort than other stormwater control measures. While this effort needn’t be complex or costly, it does need to be consistent. Before selecting a RWH system, the owner and designer must understand the daily and weekly operational effort needed and determine that this is feasible for the site.

## 25.4. Design

The designer should become familiar with the complete design, construction, and operation & maintenance information before beginning the design process for a specific site. The following design steps are roughly in chronological order, but some steps should happen concurrently.

### 25.4.1. Design Step 1: Determine Uses for Harvested Rainwater

RWHs typically serve one or more non-potable water demands, so an early design step is to identify these uses. Water designated “**non-potable**” has not been treated to or tested for the standards applied to potable (drinking) water. Non-potable water is unsuitable for drinking, hand washing, bathing, dishwashing, and pool/spa filling.

Table 25-4 highlights possible uses for harvested rainwater. The designer must understand the pros and cons of the proposed use before speaking with the owner. The designer and owner must also be aware that the use of RWH systems for stormwater credit requires that these uses must continue. If the non-potable water demand ceases because of a change to the site, the local government and/or NCDENR will require that an alternative non-potable water use may be found or that a properly designed BMP treatment system be installed on site to replace the RWH system.



**Table 25-4. Potential Uses for Harvested Rainwater**

<p><b>Irrigation – Hand watering</b></p>	<p><b>Pros:</b> The water does not require additional treatment before use, there is a simple distribution system (gravity or small pump), and a back-up to the cistern is not necessary because the owner can hand water from a separate spigot when needed.</p> <p><b>Cons:</b> This use depends on site owner/user to initiate use of the water and much of storage will be dedicated to detention and will rarely be available for irrigation.</p>
<p><b>Irrigation – Automated Systems</b></p>	<p><b>Pros:</b> Can significantly reduce the use of potable water. The pump system is similar to systems used for irrigation ponds, on-site water and wastewater systems, and building plumbing systems. Therefore, maintenance personnel will have typically have applicable experience with installation and maintenance.</p> <p><b>Cons:</b> There will be added cost to operate and maintain a pump instead of relying on the system pressure from a domestic water system.</p> <p><b>Considerations:</b> Harvested water may require additional treatment before entering the distribution system to prevent irrigation nozzles from clogging. The distribution system may be controlled using a “smart” irrigation controller. A potable water back-up to the cistern may be necessary. Seasonal operation should be considered to optimize storage.</p>
<p><b>Toilet Flushing</b></p>	<p><b>Pros:</b> Consistent, automated, year-round use on commercial and institutional sites. Visible, sustainable building feature. Appeals to owners/developers interested in green building.</p> <p><b>Cons:</b> Harvested water requires additional treatment per the NC Plumbing Code. More complex distribution system than irrigation application due to treatment requirements. Requires a separate set of plumbing for toilet and urinal flushing, which is a cost factor. Increased risk of cross-connection requires physical and educational controls.</p>
<p><b>Vehicle Washing</b></p>	<p><b>Pros:</b> Hand washing of vehicles a common use. Use in automated systems also possible. No additional treatment is typically needed.</p> <p><b>Cons:</b> Vehicle washing must be done on year-round on a regular basis.</p>

<p><b>Cooling Tower Make-up</b></p>	<p><b>Pros:</b> This use is present on many commercial, institutional, and industrial sites. Where present, this use typically represents the largest water demand at the site.</p> <p><b>Cons:</b> Cooling towers require additional treatment for all waer sources, including potable water (rainwater will require significantly more treatment). Treating harvested rainwater will increase the cost versus treating potable water. However, the payback time may be short due to the high volume of consumption.</p> <p><b>Considerations:</b> When implemented, harvested rainwater for cooling tower make-up is typically blended with other non-potable water supplies because of the variability in the quantity and quality of rainwater. The entity operating the cooling tower system will know the specific water quality parameters and may choose to use a specialty consultant for the treatment system design. In some cases, a small reverse osmosis (RO) system is used.</p>
<p><b>Street Sweeper Tank Filling</b></p>	<p><b>Pros:</b> There is potential for a large savings of potable water and a consistent, year round need for the water.</p> <p><b>Cons:</b> May require filtration to a specific particle size to prevent clogging spray nozzles.</p> <p><b>Considerations:</b> May require a more powerful pump than other applications because fittings for the water tanks are typically sized for connection to a fire hydrant.</p>
<p><b>Laundry</b></p>	<p><b>Pros:</b> Laundry can provide a consistent, year-round use.</p> <p><b>Cons:</b> Additional treatment may be required, depending on the use, catchment area, and any special water quality requirements for the specific application.</p>
<p><b>Animal Systems</b></p>	<p><b>Pros:</b> Flushing animal waste tanks/systems, washing kennels and pens, etc. can provide a consistent, year-round use.</p> <p><b>Cons:</b> Additional treatment may be required, depending on the use, catchment area, and any special water quality requirements for the specific application.</p>

**25.4.2. Design Step 2: Discuss Non-Potable Water Use and System Operation & Maintenance with Owner**

Before pursuing a RWH design beyond the conceptual stage, the designer shall meet with the owner to explain the non-potable water use requirement and the operation and maintenance requirements of the proposed system. RWH systems require more hands-on operation and more frequent maintenance than other stormwater controls. The cost of these requirements should be offset by savings during the construction phase and/or during operation. This preliminary discussion should involve a subset of the following people, as applicable to the site:

**Table 25-5. Entities to Meet with Before Design of the RWH System**

<b>Homeowner</b>	For single-family homes where the resident-owner is involved in design and management of the RWH system.
<b>Owner and their representatives</b>	<p>For commercial, institutional, and industrial sites that are developed or renovated by the owner, the affected groups may include:</p> <ul style="list-style-type: none"> <li>○ Property manager or building engineer</li> <li>○ In-house maintenance staff responsible for the operation and maintenance of plumbing, grounds and landscape, irrigation systems, on-site water and wastewater treatment systems, control systems, etc.</li> <li>○ Contracted maintenance staff (e.g. landscaping contractor)</li> </ul>
<b>Developer</b>	At sites where the post-construction owners are not involved in the design, development team will be responsible for conveying information about restrictive covenants, recorded maintenance agreements, and similar information to buyers, including separate homebuilders in a subdivision.
<b>Design team</b>	<p>The professionals involved will depend on the scale of the site and the planned harvested rainwater uses, but may include:</p> <ul style="list-style-type: none"> <li>○ Architect</li> <li>○ Civil engineer</li> <li>○ Plumbing, mechanical, electrical (PME) engineer(s)</li> <li>○ Landscape architect</li> <li>○ Irrigation designer</li> </ul>

Before meeting, the designer should review the design, construction, and operation & maintenance portion of this chapter and prepare a list of questions for the team. Key objectives in the discussion include:

- Selecting one or more uses for the harvested rainwater. (See Section 25.4.1.)
- Explaining the level of operation and maintenance involvement needed and determining if the owner will be capable of this effort. (See Section 25.5)
- Clarifying the goals for the RWH system. This may range from exclusively stormwater management to primarily water conservation. This information is needed to optimize the sizing of the system. (See Section 25.1.1)
- Soliciting information related to selecting quantifying the non-potable water demand. (See Section 25.3.4)

### 25.4.3. Design Step 3: Calculate Non-Potable Water Demand

Calculating the non-potable water demand to be met with harvested rainwater is a key component of the stormwater design. In RWH design, demand estimates should not be over or under estimated. If the designer significantly over-estimates the non-potable water demand, the cistern will frequently be full and will provide less treatment than intended. Municipalities may require submittal of documentation that the system is functioning per design. If the designer significantly under-estimates the demand, then the cistern may frequently be empty and the owner will not see the planned water savings planned.



Figure 25-2. Harvested rainwater used in irrigation and vehicle washing. (NCSU-BAE)

The designer shall include documentation of the demand calculations and the assumptions and data sources behind these calculations in the design submittal. The demand estimates should be calculated using the best available information for the site. Possible data sources include:

**Table 25-5. Possible Data Sources for Water Use from the Cistern**

<p>Metered water consumption</p>	<p>For existing sites being retrofitted with a RWH system, actual historic meter data can be used.</p>
<p>Irrigation design calculations</p>	<p>For sites where an irrigation design is prepared, this can be incorporated into the demand calculations.</p> <ul style="list-style-type: none"> <li>○ Detailed irrigation designs consider soil type, plant species and water need, and local ET rates.</li> <li>○ Other designs may be less site-specific, but still provide helpful estimates, such as the inches per week by month.</li> <li>○ Designers may choose to maximize irrigation as described in the box below. This approach will further reduce the need for other BMPs on-site, but will result in more complicated design and operation.</li> </ul>
<p>Specialty design calculations</p>	<p>For cooling tower make-up, animal systems, or other specialty uses where water use is integral to the site’s function, water demand calculations will be part of the overall design.</p>
<p>Field Observations</p>	<p>For some practices, field observations may be required to determine the design demand. For example, a vehicle washing station may require field observation of the time spent washing each vehicle.</p>
<p>Toilet Flushing Estimates</p>	<p>For sites designing RWH systems for toilet flushing, the calculations can be trickier than other uses.</p> <ul style="list-style-type: none"> <li>○ Good starting points include the plumbing design fixture counts, gallons per flush, building occupancy information, and potable water demand information.</li> <li>○ However, it is important to note that these other design calculations typically over-estimate the demand for toilet and urinal flushing. In particular, this is because estimation methods are often based on historic data for buildings without low-flow fixtures. Therefore, this demand should be calculated in multiple ways before selecting a design demand.</li> <li>○ In addition to the volume, it is important to consider whether there is seasonality to the demand. For example, a school would have drastically lower demand during certain months while an office building may see fairly even demand through the year.</li> </ul>

***Maximizing Irrigation: An Alternative Approach for Irrigation-Based Systems***

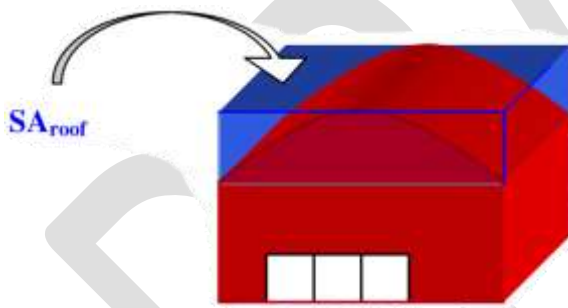
Typical irrigation design is based on the *minimum* irrigation needed to maintain health and quality in the vegetation. This conserves water, but limits the stormwater benefits in irrigation-based RWH systems because cisterns remain full in the non-growing season.

The alternate approach *maximizes* the amount of irrigation by calculating the maximum amount of water that can be applied while maintaining health and quality in the vegetation and preventing runoff of the irrigated water. This is done by considering the soils, slopes, vegetation, evapotranspiration rates, irrigation rates, and other factors. Designers may be familiar with this concept from non-discharge wastewater systems that employ irrigation for disposal.

Designers wishing to maximize irrigation on a site should prepare irrigation calculations in consultation with the owner and other professionals as needed, such as soil agronomists, soil scientists, or irrigation designers.

Irrigation control systems for sites employing maximized irrigation should be designed to switch to minimum irrigation rates once a cistern runs dry and a make-up supply is

**25.4.4. Design Step 4: Determine Drainage Area**



**Figure 25.3. Determining the Roof Surface Area (NCSU-BAE)**

For the majority of systems, the drainage area (catchment surface) is a rooftop. In general, rooftop runoff will have higher water quality than other surfaces. Therefore, the drainage area will be equal to the roof area. Note that the SA<sub>roof</sub> variable is the area of the roof in plan view. Collecting runoff from other surfaces, such as parking lots, sidewalks and landscaped areas is also allowed but additional filtration/treatment may be required.

**25.4.5. Design Step 5: Site the Cistern and Design Collection System**

The cistern should be sited in a location where the catchment area can drain by gravity. Also, consider the design of the downstream BMP when selecting a site. The collection system may consist solely of gutters and downspouts. At larger sites it may also include stormwater pipes and inlets. For sizing the collection systems on a single family home or other small building, designers may refer to the NCSU Extension Publication [Rainwater Harvesting: Guidance for Homeowners](#), which includes tables for sizing gutters and downspouts.



**Figure 25.4. Examples of Cistern Siting and Collection System Design (NCSU-BAE)**

#### **25.4.6. Design Step 6: Design Make-Up Water Supply**

The inclusion of a make-up water supply – to be used if no harvested rainwater is available – is an optional element in terms of the stormwater management performance of the RWH system. The inclusion of a make-up supply and the design of the supply depend of the non-potable water demands at the site.

For sites where the only use is irrigation, the designer may choose not to include a make-up water supply. If the cistern runs dry, the owner manually switches the hose to a spigot fed by potable water. Some non-potable water uses require an automated make-up water supply. For example, a toilet flushing system can't be switched off during a drought. Design considerations for an automated make-up supply include:

Figures 25.5 and 25.6 show possible configurations of automated make-up water supply. Table 25-6 lists design considerations for automated make-up water supply



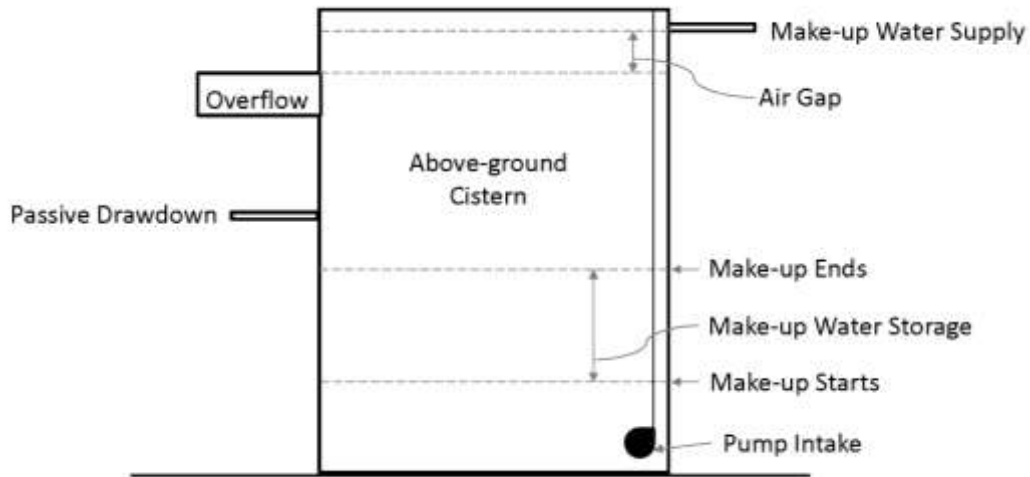


Figure 25-5. Example configuration of Make-up Water and Air Gap in an Above-ground Cistern (UNC-Chapel Hill)

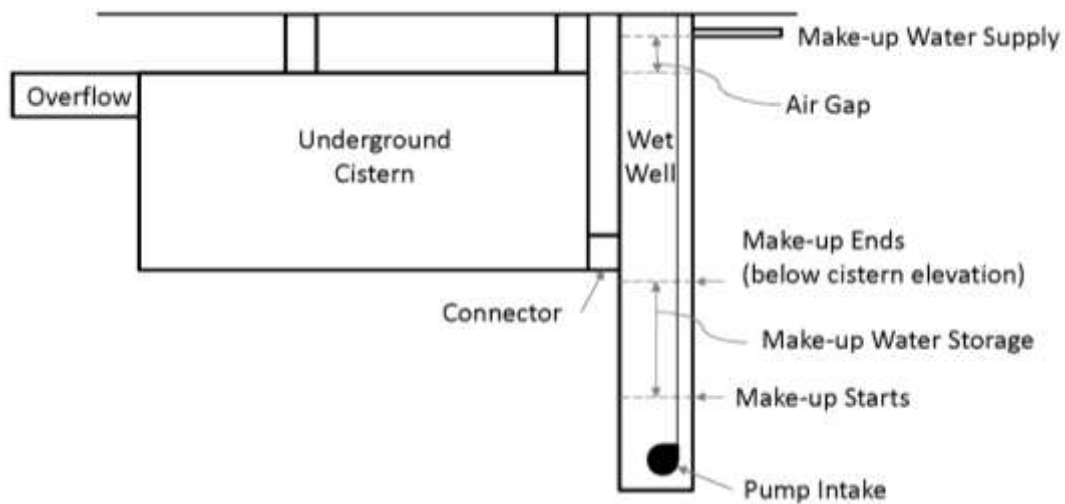


Figure 25-6. Example of the use of wet wells with an underground cistern to eliminate potable water storage in the cistern (UNC-Chapel Hill)



**Table 25-6. Design Considerations for Automated Make-Up Water Supply**

Specialty design calculations	For cooling tower make-up, animal systems, or other specialty uses where water use is integral to the site’s function, water demand calculations will be part of the overall design.
Field Observations	For some practices, field observations may be required to determine the design demand. For example, a washing station may require field observation of the time spent washing each vehicle.
Air-gap	An air gap and other cross-connection requirements per the NC Administrative Code, NC Building Code, and the local public water supplier must be followed when combining potable and non-potable waters.
Minimal make-up water storage	If a secondary or makeup water supply is used, it shall be designed to place a minimal amount of volume in the cistern at any one time. The design must allow for adequate storage for the full volume of the next design storm.
Level Indicators	Automatic make-up is typically triggered by a float switch, pressure transducer, or level indicator. The water elevation that triggers the make-up must be high enough to avoid running the pumps dry. The elevation that triggers the make-up must be lower than the passive draw-down orifice (if applicable).
Wet wells	An option for larger, underground cisterns is to have a separate wet well at a lower elevation. This eliminates the storage of make-up water in the cistern.
Other non-potable water supplies	Well water is sometimes used as a make-up supply. Reclaimed water and greywater are also sometimes used, but this requires the entire RWH system to meet the more stringent regulations for reclaimed water or greywater.

**25.4.7. Design Step 7: Other Supplementary Water Supplies**

Some RWH systems incorporate the use of condensate, foundation drainage, or other supplementary water supplies. Including other sources is optional.

Considerations for these systems:

- If water is allowed to be discharged to surface water, it can be evaluated for inclusion in a RWH system.
- For single family homes, the volume of these supplemental sources is negligible and doesn’t need to be calculated.
- For large buildings, the volume of condensate from air handlers or foundation drainage delivered via sump pumps or well points can be considerable. For these

systems, the flow rates for supplemental water supplies must be calculated and incorporated into the water balance model.

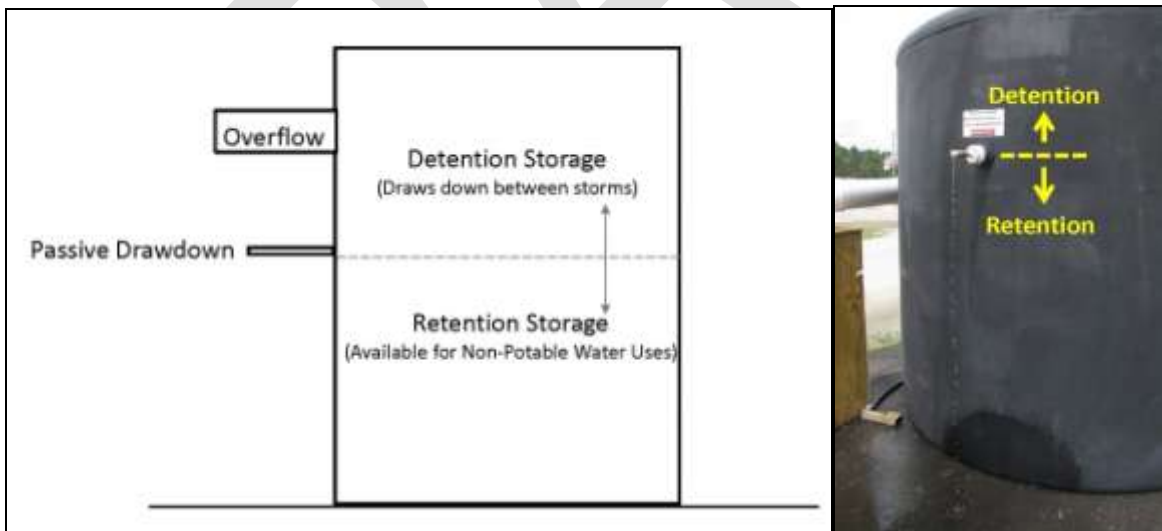
- When incorporating condensate from air handling units, confirm with the Mechanical Engineer and the building owner that the system uses UV disinfection rather than biocide tablets. Also check on site-specific practices for cleaning air handling units.
- When incorporating flows that originate inside the building, confirm that only the desired source is included. In conventional systems, the condensate often discharges to a floor drain before going to the sanitary sewer. Floor drains must continue to discharge to the sanitary sewer, not to the cistern.

**25.4.8. Design Step 8: Determine the if a Passive Drawdown is Needed**

To meet water quality requirements cisterns shall be sized to capture a minimum of 86% of the total runoff as demonstrated through water balance calculations. In many RWH systems the required water captured in the cistern will exceed the non-potable water demands at the site, so passive drawdown will be required. In any RWH system used solely for seasonal irrigation, a passive drawdown will be needed.

The storage in the cistern will be divided into two zones:

- detention volume, which will discharge via the passive drawdown orifice over 2-5 days
- retention volume, which will remain available for non-potable water uses



**Figure 25-7. Passive Release and Storage Zones. (UNC-CH and NCSU BAE)**

The passive drawdown will discharge to a downstream vegetated infiltration area meeting the requirement of this chapter (see Design Step Z) or to a stormwater BMP sized per another chapter of this manual. This discharge will occur at a slow rate over 2-5 days, so the downstream vegetated infiltration area or BMP will be smaller than the treatment

area that would be required if a RWH system were not used. This discharge empties space in the cistern that will be used to store runoff from the next rainfall event.

*To determine if a passive drawdown is required:*

1. Calculate the Water Quality Runoff Volume per Section 3.3 of this Manual.
2. Calculate the average 5-day, year-round non-potable demand. For seasonal uses such as irrigation, this will be zero. *If the only non-potable water demand is seasonal irrigation, then a passive drawdown is needed.*

**Examples:**

An animal shelter uses harvested rainwater to wash down kennels. This occurs 7 days per week, year round, so  $V_{5day} = 5 * V_{daily}$ .

If an office building uses rainwater for toilet flushing and has a high demand on weekdays (x gal/day) and a low demand on weekends (y gal/day), the average 5 day demand would be calculated as  $V_{5day} = 5 * (5x + 2y)/7$ .

3. If the Water Quality Runoff Volume is greater than the average 5-day, year-round demand ( $V_{5day}$ ), then a passive drawdown is needed.

**Alternate Design Option: Passive Release Valve**

If a RWH System has active operational management, such as an on-site grounds manager who cares for the irrigation system, then the passive release mechanism may be equipped with a valve. This option is not recommend for sites without on-site operation and maintenance personnel.

In this situation, the designer bases the detention storage on the low-season demand, but the cistern volume on the high-season demand. In the fall, as irrigation season concludes, the site manager opens the valve to allow the detention volume to passively drain. In the spring, when irrigation season begins and the full cistern volume can be drawn down in 5 days, the site manager closes the valve to prevent the passive release.

If this alternative is used, the handle of the valve shall be removed or locked to prevent tampering with the release mechanism.

**25.4.9. Design Step 9: Determine the Detention Storage Volume**

The detention storage above the passive drawdown can be approximated as the Water Quality Runoff Volume, which is calculated per Section 3.3 of this Manual.

For systems with a consistent, year-round demand, such as toilet flushing, it is possible that the detention volume required will be less than the water quality volume. This can be determined through modeling or adjusted using the average 5-day demand as shown below. Seasonal demand cannot be used to adjust the detention volume.

**Adjusted detention volume,  $V_{d-adj}$ :**

$$V_{d-adj} = V_d - V_{5day}$$

Where:

- $V_{d-adj}$  = Adjusted Detention volume (gal)
- $V_d$  = Detention volume (gal)
- $V_{5day}$  = Average 5-day water consumption for the consistent, year-round demand (gal)

The detention volume can be further adjusted and optimized through iterative water balance calculations.

**25.4.10. Design Step 10: Size the Passive Drawdown Orifice**

The steps for designing a passive release mechanism are as follows:

1. Determine the height of the passive drawdown orifice.
2. The passive release orifice should be placed such that the detention storage volume is equivalent to or greater than the design rainfall volume. Utilize volume calculation based on the cistern’s shape to determine this height.
3. Choose the drawdown time for the detention storage volume. To receive stormwater credit, the design rainfall/detention storage volume must drain from the system within 2-5 days. A drawdown time of 2.5-3 days is recommended, as this is slightly greater than the minimum but maximizes the capture of the water quality volume by preparing the system for the next rain event quickly.

- Calculate the flow rate associated with the chosen drawdown time:

**Passive Release Flow Rate, Q:**

$$Q = \frac{V_d}{t} \cdot \left( \frac{1}{1440} \right)$$

Where:

Q = passive release flow rate (gal/min)

V<sub>d</sub> = detention storage volume (gal)

t = chosen drawdown time (days)

- Determine the head on the passive release orifice when the tank is full. This is equal to the distance from the center of the passive release orifice and to invert of the overflow pipe.
- Calculate the cross-sectional area of the passive release orifice:

**Cross-sectional area of the passive release orifice, A:**

$$A = \frac{Q}{\sqrt{64.4h}} \cdot 144$$

Where:

A = cross-sectional area of the passive release orifice (in<sup>2</sup>)

h = head on the passive release orifice when cistern is full (ft)

- Determine the diameter of the passive release orifice:

**Diameter of the passive drawdown orifice, d:**

$$d = \sqrt{\frac{4 \cdot A}{\pi}}$$

Where:

A = cross-sectional area of the passive release orifice (in<sup>2</sup>)

**25.4.11. Design Step 11: Water Balance Calculations and Cistern Sizing**

To receive stormwater credit, the cistern shall be sized to capture a minimum of 86% of the total annual runoff as demonstrated through water balance calculations. Note that this is 86% of runoff from all storms, not from a water quality storm. This 86% volume capture is equivalent to the typical volume of water treated annually by a wet pond and

other non-infiltrating stormwater practices when designed to capture the water quality volume and detaining the water volume for slightly more than 2 days (Smolek et al. 2012).



The water balance may be calculated using the [NCSU Water Harvesting Model](#) or another continuous-simulation hydrologic model that calculates the water balance on a daily or more frequent time-step using a minimum of 5 representative years of actual rainfall records. The model shall account for withdrawals from the cistern for usage and for the active or passive drawdown as well as additions to the cistern by rainfall and runoff and by a make-up water source (if applicable).

The following information is needed to begin the water balance calculations:

- Catchment area (drainage area).
- Capture factor for the drainage area or other variable(s) used to calculate runoff from rainfall.
- Rainfall records for a nearby city with a minimum of 5 representative years of data at a daily or more frequent time-step.
- Non-potable water demand(s) – either consistent daily values or with values that vary by day of the week or by month (seasonal variation).
- Make-up water supply – if make-up water supply is discharged into the cistern, know the trigger points for started and ending the flow.
- Supplemental water supply flow rate (e.g. Condensate from air handling units, discharge from foundation drains).
- Detention volume.
- Passive drawdown release rate.

The cistern size will be optimized through iterative calculations. The NCSU Rainwater Harvester Model will calculate a cistern size based on the above inputs. If using a model that doesn't perform this calculation, the iterative calculations can be started using a capacity in gallons equal to the square feet of catchment area.

The key output from the water balance is the total annual runoff volume captured in the cistern, which must be 86% or higher. In the NCSU Rainwater Harvester Model this output is called the **"Total Volume Captured."**

#### **25.4.12. Design Step 12: Design Anti-Clogging Measures for the Passive Drawdown**

Because the orifice for passive drawdown is often very small, the passive release mechanism should be equipped with some type of filter, located on the inside of the tank, to prevent clogging. An example low-flow orifice system is presented in a technical memo by NC State University Biological & Agricultural Engineering.



**Figure 25-8. Anti-Clogging Passive Drawdown Mechanism (NCSU BAE)**

**25.4.13. Design Step 13: Design the BMP Downstream of the Passive Drawdown (If Applicable)**



**Figure 25-9. A bioretention cell adjacent to cisterns (NCSU BAE)**

Passive drawdown flow must be discharged to an infiltration or filtration device meeting the requirements listed below or to a stormwater BMP sized per another chapter of this manual. The small outlet diameter results in relatively small flows that can be handled by small devices. Note that only the passive drawdown, NOT the overflow, shall be directed to a filtration or infiltration BMP device. If overflow were directed to the BMP, the device footprint would need to be substantially larger.

***Passive Drawdown to Vegetated Receiving Area***

For single-family homes and other sites where in-situ soil testing indicates a soil infiltration rate exceeding 0.5 in/hr, the passive drawdown system may discharge to a vegetated receiving area. The vegetated receiving area shall have a minimum size of 6 feet in width by 12 feet in length and have a slope of less than 7 percent. If necessary, the vegetated receiving area shall be graded so that flow will be uniform. The vegetated receiving area shall be tilled if it is compacted and a dense growth of vegetation shall be maintained.



**Passive Drawdown to Small BMP**

For sites other than single family homes where in-situ soil testing indicates a soil infiltration rate that is less than 0.5 in/hr, a small BMP shall be provided. Typically, this BMP will be a sand filter, infiltration system, bioretention cell, or a small wetland. As a general rule of thumb, this BMP shall be sized so that its surface area is equal to 5% of the impervious area draining to the cistern. However, the designer may propose another sizing metric with technical justification.

**25.4.14. Design Step 14: Design the Cistern Overflow and Safe Conveyance of the 10-year, 24-hour Storm**

RWH systems shall include a mechanism for safely conveying the 10-year, 24-hour storm, which may be accomplished through bypass or detention. The RWH system can also be designed to meet local requirements for peak attenuation and volume control for larger storms. First, the designer must determine if the flow in excess of the design storm will enter the cistern or be bypassed before reaching the cistern.



**Figure 25-10. Example of an overflow at an NCDOT Facility (NCSU BAE)**

- For single-family homes or other small catchment areas, it may be easier to route the downspouts to the cistern then design an overflow from the cistern. For sizing the overflow at these sites, designers may refer to the NCSU Extension Publication [Rainwater Harvesting: Guidance for Homeowners](#).
- For larger systems, it may be better to use a diversion upstream of the cistern. This may prevent issues with surcharging from the cistern. In these cases an overflow should still be included in the cistern design.
- The elevation of the overflow pipe shall be at or above the designed cistern volume, including above the detention volume.

Second, the downstream overflow conveyance must be designed. Overflows or bypass water shall be discharged in a non-erosive manner for the 10-year rainfall event. These flows can be directly discharged to the storm sewer network or to a natural water body. From the point of release, the path and destination of overflow and by-pass discharge must be clearly indicated on the plans.

**25.4.15. Design Step 15: Active Release Mechanism System**

If a RWH System has active operational management, such as an on-site grounds manager who cares for the irrigation system, then a control system that employs an active release mechanism may be used. The active release allows the cistern volume dedicated to detention of the water quality volume and/or detention for peak discharge control to also be used to maximize harvested rainwater storage. This optimizes cistern volume, water conservation, and stormwater control.



An automated release valve is placed at the outlet of the RWH system. Discharge from the valve is initiated by a sophisticated control system with software that has been programmed specifically for the site. The program retrieves the precipitation forecast from the National Oceanic Atmospheric Administration (NOAA), which predicts the probability of rainfall occurrence and rainfall totals. The program calculates the needed storage based on the predicted rainfall and evaluates the available storage based on an automated reading of the cistern water level (e.g. by pressure transducer). If the needed storage volume is available, the release valve stays shut. If the needed volume is not available, the release valve is opened and stored water is released from the cistern until the needed storage volume is available.

Design and construction of active release systems requires programming and testing of the control system. Off-the-shelf software for incorporating passive release is not available. However, existing control system software can be utilized. While the active release systems are new to North Carolina, they have been developed in cities with combined sewers where active release systems are used to prevent combined sewer overflows. Therefore, it is possible to find designers and vendors who are familiar with these systems.

Design of the active release systems also requires water balance calculations. These calculations must meet the requirements of this chapter, but will be more complicated than most models allow.

Active release RWH devices must treat the water quality volume. Options for treating the water quality volume in conjunction with an active release include:

- The designer may choose to provide full water quality treatment upstream of the cistern. (e.g. sand filter sized per the Sand Filter chapter of this manual) In this case, the primary objective of the cistern is potable water conservation and the storage volume of the cistern can be determined independently of the water quality volume by optimizing for the usage.
- The active release could be used in conjunction with a passive drawdown, where the passive drawdown discharges to a downstream vegetated infiltration area or other downstream BMP.
- All of the water discharged via the active release could be discharged to a downstream BMP.

The active release mechanism addresses many of the disadvantages of the passive release mechanism. The use of weather forecasting ensures that water is only released from the system if it will be replaced by an imminent precipitation event. This eliminates the 'wasting' of needed water, as well as the decrease in the volume of usable storage within the RWH system. Thus, when applied to an existing RWH system, the full system volume is still available to the user to meet water demands. When applied to the design of a new system, there is no need for including extra volume (and cost) to compensate for a loss in storage. Finally, the program logic prevents the release of stored water during a precipitation event, which is a primary goal of stormwater management.

Drawbacks to the active release mechanism include cost, complexity and resource requirements. The installation of the equipment and program logic is typically expensive. Furthermore, the complexity of the programming logic and the potential for technical glitches requires oversight by a highly knowledgeable company or individual, which can also be expensive. Finally, as the program is based upon the ability to access NOAA forecasts, there must be uninterrupted power and internet accessibility at the site. At large scale or actively managed sites, the advantages may outweigh these disadvantages.

**25.4.16. Design Step 16: Design Pre-Treatment**

One or more pre-treatment devices shall be included upstream of the cistern to minimize gross and coarse solids collection in the tank. A pretreatment device helps to eliminate debris such as leaves, roof shingle grit, pine straw, trash, etc. This may take the form of a first flush diverter, screen, settling chamber, or other device appropriate to the system.



**Figure 25.11. Fine filter used upstream of an underground cistern (left), gutter screen (center), downspout screen (right) (NCSU BAE left and center and UNC-CH right).**

Options of pre-treatment devices are listed in Table 25-7 below.

**Table 25-7. Options for Pre-Treatment of Harvested Rainwater**

<b>Gutter screens</b>	Can prevent leaves and other debris from entering the system.
<b>Downspout screens and filters</b>	Are placed inline with the downspout before it enters the cistern. These can be purchased or constructed with a variety of mesh sizes. They should be placed at a height and location that provides the best access for maintenance, as they will need to be cleaned frequently.
<b>Basket Filters and In-Line Strainers</b>	Include configurations suitable for underground systems.
<b>First flush diverters</b>	Hold and slowly discharge the first 0.04 inches of rainfall, preventing the most polluted water from entering the cistern. The first flush diverter should be discharged to the same downstream BMP as the passive release mechanism. (Note that this first flush volume is not equivalent to the water quality volume used in BMP design.) First flush diverters should be installed at a height that can be accessed without a ladder, as they require frequent cleaning.
<b>Hydrodynamic separators and vortex filters</b>	Are sized by flow rate and may include integral screens. Though more expensive and complex, they provide an option with a longer interval between cleaning.
<b>Settling tanks, oil-grit separators, forebays</b>	May be appropriate for stormwater harvesting systems that capture surface runoff
<b>Sand filters</b>	If designed per this manual, are acceptable as pre-treatment to the cistern. They would typically be used only when higher water quality is needed.

**25.4.17. Design Step 17: Select and Specify Cistern Materials**

A wide variety of materials are available and acceptable for use as the cistern component in RWH systems.

For single family homes and other small rooftop collection systems, above-ground tanks are most common. Above-ground cisterns are commercially available in sizes ranging from 50 gallon rain barrels to tanks with capacities well over 10,000 gallons. Below ground cisterns are typically selected for systems over 50,000 gallons.

Table 25-8 provides guidance on specifying materials for above ground and below ground cisterns.

**Table 25-8. Materials for Above and Below Ground Cisterns**

**Above ground cisterns**

- Above ground cisterns should be of a material or color that prevents light from entering the cistern, which helps prevent algae growth within the cistern.
- Materials for above ground tanks include plastics and metal tanks with internal bladders. Sometimes wooden or stone facades are used for aesthetic reasons.
- Though most tanks are cylindrical, narrow width options are available.

**Below ground cisterns**

- For underground cisterns, the allowable leakage rate for must be determined during design. The specified cistern materials and construction methods shall be capable of providing a level of water-tightness that reflects the allowable leakage rate.
- In-situ testing for water-tightness is required. It is the designer’s responsibility to determine the appropriate level of testing for the site and the materials.
- Materials for below-ground tanks include plastics and fiberglass. Other materials may be used if they are lined with a water-tight membrane. Non-proprietary systems include gravel and cast-in-place concrete. Proprietary systems include pipes (plastic, concrete, and metal), vaults, and modular proprietary products that provide more void space than gravel.

In addition to meeting the requirements of this chapter, all cisterns shall follow the applicable manufacturer requirements, product standards, and industry guidelines to ensure lasting effectiveness. A cistern level indicator is a recommended component. The simplest level indicators attach to the exterior of the cistern and provide a quick visual indicator of water level.



**Figure 25-12. Metal cistern under construction (left), underground concrete vault wrapped in an impermeable liner (center) and a series of plastic cisterns (right) (UNC-CH left and NCSU BAE center and right)**

**25.4.18. Design Step 18: Provide Maintenance Access**

The RWH system design must include maintenance access for each component. This will vary by site and installation type, but key issues in the design are listed in Table 25-9 below.

**Table 25-9. Providing Maintenance Access for Cisterns**

<p><b>All cisterns</b></p>	<ul style="list-style-type: none"> <li>• Include a drawdown valve so that the cistern can be drained for maintenance</li> <li>• Cisterns must include a maintenance access that allow cleaning</li> <li>• If submerged pumps are used, there must be a mechanism to safely pull the pumps for maintenance.</li> <li>• Collection systems should include cleanouts or manholes at bends in the pipe to allow for cleaning.</li> </ul>
<p><b>Above ground cisterns</b></p>	<ul style="list-style-type: none"> <li>• If possible, downspout filters or other pre-treatment should be accessible for maintenance without the use of a ladder.</li> <li>• Include an access point that allows visual access to the cistern interior.</li> <li>• For safety reasons, access hatches should be locked or require special tools for opening, or otherwise be inaccessible to the general public.</li> <li>• Depending on the height of the cistern, other provision may be needed for maintenance, such as tie-off points for workers.</li> </ul>
<p><b>Below ground cisterns</b></p>	<ul style="list-style-type: none"> <li>• Include manways that allow for the set-up of a tripod for confined space entry. This requires level space surrounding the opening and vertical clearance.</li> <li>• A minimum of one access point per cistern tank and per treatment devices should be located where they can be driven to by a pump truck. The location must also have sufficient vertical clearance for the pump truck.</li> <li>• Underground cisterns should be a sufficient distance from building foundations and other infrastructure to allow excavation to the cistern structure in case repairs are needed.</li> </ul>

**25.4.19. Design Step 19: Buoyancy Calculations or Footing Design for Cisterns**

A properly designed footing for the cistern must be designed if the load of the cistern at full capacity is greater than that which underlying soils will support. If it is buried, buoyancy calculations must be provided to show the cistern will not float when empty. Buoyancy calculations and flotation constraints must be provided if any part of the buried cistern is below the seasonal high water table, or if the area is subject to flooding.

**25.4.20. Design Step 20: Distribution System**

All RWH systems must include means to utilize the harvested water. Therefore, the plans and specifications must include both the elements of functional distribution system appropriate to the intended uses plus specifications for testing the system during construction.

At the simplest level, a cistern to be used for hand watering will include a spigot at a low elevation that is fed by gravity. However, a majority of cisterns will include pumps and piping of some level of complexity to convey harvested water from the cistern to the usage location.

The distribution system may include the following elements:

- Pump intakes - Pump intakes should be positioned above the bottom of the cistern to account for the inevitable accumulation of sediment. It is also desirable for the intake to be below the water surface to avoid suction of floating debris.
- Pump - An appropriate pump shall be selected to provide adequate pressure for its designated uses.
- Pneumatic tanks - A bladder tank may be used with the pump to minimize pressure fluctuations and wear on the pump.
- Control system
- Distribution piping

**25.4.21. Design Step 21: Usage Metering**



**Figure 25-13. A water meter from the local public water/sewer provider is installed where harvested rainwater the building to be used for toilet flushing. (UNC-CH)**

Many owners choose to meter the harvested rainwater distributed to the uses as a metric of sustainability or cost savings. For indoor uses that discharge to the sanitary sewer, such as toilet flushing, the public water supplier may require metering. Because most public water suppliers base sewer billing on water consumption, these agencies are concerned about lost revenue due to rainwater harvesting. The agency may require their meter to be installed on the harvested rainwater distribution pipe entering the building to be used as the basis for sewer billing. For small sites, the agency may allow estimated payments without a meter.



**25.4.22. Design Step 22: Point-of-Use Treatment (If Needed)**

Point-of-use treatment may include filtration or disinfection. Indoor uses require treatment per the building code. The treatment for outdoor uses is determined by the designer and is generally guided by usage. For example, additional filtration may be adding to an irrigation system to prevent clogging irrigation heads.

Point-of-use treatment adds operation and maintenance and introduces more points for the distribution systems to fail. Therefore, it is important to weigh the need for each component and the appropriate level of technology. Filtration techniques range from simple filters on pump intakes, to more complex systems like auto-backwashing disc filters. Disinfection techniques typically involve chlorination or UV treatment.

**25.4.23. Design Step 22: Irrigation System (If Applicable)**



**Figure 25-14. An Irrigation Controller (NCSU BAE)**

Rain sensors should be installed for all automated irrigation systems to insure that turf and landscaped areas are not over-watered.

All spigots, hose bibs or other outlets for the harvested rainwater should be of a type, or secured in a manner, that permits operation only by authorized personnel, such as a locked below grade vault or a spigot that can only be operated by a tool.

**25.4.24. Design Step 24: Signage**



**Figure 25-14. Signage adjacent to a commode (NCSU BAE)**

All harvested rainwater outlets (e.g. spigots, hose bibs), storage facilities, and appurtenances shall be labeled as “Non-Potable Water” or “Non-Potable Water Do Not Drink” to warn the public and others that the water is not intended for drinking.

These required locations may include:

- Cistern
- Hose bibs
- Quick-coupling locations for the irrigation system
- Irrigation controller
- Toilet flushing locations

Passive drawdown devices, when employed, shall be marked with signage or labels that are visible to owners and maintenance personnel. This is to prevent the passive discharge drawdown from being plugged or capped.

**25.4.25. Design Step 25: Reviews by Non-Stormwater Agencies**

RWH projects may require reviews by agencies that typically do not review stormwater designs. The primary conditions that would trigger these reviews are:

- Indoor Use, which triggers the Building Code
- Uses that discharge to the Sanitary Sewer (e.g. Toilet Flushing, Laundry), which may trigger review by the Local Water Supplier
- Potable Water Make-up, which triggers cross-connection control requirements

**Table 25-10. Non-Stormwater Agencies who May Review RWH Systems**

<b>Regulation:</b> Review Agency	<b>Considerations</b>
<p><b>NC Plumbing Code:</b> Local government or state construction office (state projects)</p>	<p>The NC Plumbing Code applies only if the harvested rainwater is brought inside a building. The code is uniform throughout the state and is implemented by local jurisdictions and the State via plan reviews, building inspections and the issuance of a certificates and/or permits.</p> <p>RWH systems are specifically addressed in Section 608 and Appendix C-1; although it is possible for other portions of the Code to apply to these systems.</p>
<p><b>NC Administrative Code:</b> NC Division of Environmental Health, Public Water Supply Section AND public water suppliers (local government, water and sewer authority, or private company)</p>	<p>The NCAC requires the implementation of backflow prevention measures to protect potable public water supplies from contamination via RWH systems.</p> <p>The NCAC is applicable when RWH systems are equipped with a backup supply via a public water supplier.</p>
<p><b>Local Water Supply:</b> Public water suppliers (may be the local government, a water and sewer authority, or a private company) AND/OR local health departments</p>	<p>The local water supply has its own regulations that serve to protect citizens and the public water supply system. These regulations may pertain to backflow prevention, metering, and/or billing, among other things.</p>



**Rainwater? Greywater? Reclaimed water?**

Those involved with designing, installing, and operating RWH systems must understand the difference between these types of water. In North Carolina, the NC Building Code and the NC Administrative Code (NCAC) contain significantly different regulations for RWH systems, greywater systems, and reclaimed water systems. In particular, the correct terminology must be used in:

- \* Submittals to review agencies
- \* Labeling the systems, and
- \* Training the operators and users.

**Rainwater Harvesting** systems collect runoff from roofs or other catchment surfaces during a rainfall event. RWH systems are not regulated separately from stormwater in the NCAC. However, indoor RWH systems are regulated in the NC Plumbing Code.

**Greywater** refers waste discharges from bathtubs/showers, sinks, and clothes washers – typically domestic wastewater other than from toilets. Greywater harvesting typically occurs at a building or site scale and includes treatment of the greywater for non-potable uses. The NC Plumbing Code specifically defines and regulates greywater systems.

**Reclaimed water** refers to treated wastewater. Reclaimed water systems operate under permits from NCDENR and meet specific water quality standards. These systems are used at the municipal scale, with the treatment and distribution by the municipality or local water and sewer authority, and at the site scale such as for a housing development or office complex. The terms “recycled water” and “water reuse” are commonly used interchangeable with “reclaimed water”. The NCAC contains a specific section that regulates reclaimed water.

## 25.5. Construction

Construction oversight by a design professional familiar with RWH system installation can help ensure that the investment results in adequate long-term performance.

### 25.5.1. Construction Step 1: Install Cistern Footing/Complete Excavation

Because cisterns are extremely heavy when full of water, the cistern base should be level to avoid the loss of storage space and/or the cistern falling over. The area occupied by the cistern should be cleared of any vegetation or debris and a level depression excavated. The depth of the depression should be at least 12-18 inches deep to avoid freezing of any pipes entering or exiting the bottom of the cistern. However, the cistern should not be buried more than 2 feet deep, to prevent the pressure of soil on the sides of the tank from causing collapse. The area of excavation should be approximately 2 feet greater in diameter than the cistern to allow for optimum positioning and room for plumbing.

For cisterns 1,500 gallons and smaller, an aggregate base 6-8 inches deep should be placed in the depression and leveled. Typically crusher run or #57 stone is used but others types are also acceptable. For cisterns greater than 1,500 gallons, a concrete pad 4-6 inches thick should be poured into the depression and leveled for the base (Figure 25-15). In cases

where the excavation of a depression is not feasible (e.g., paved surfaces or foundations), the cistern may be placed on ground surface; however, it is important that there still be a gravel or concrete base of the appropriate thickness to support the cistern. Also, any exposed piping that remains full of water between times of use should be well insulated to prevent freezing.

A concrete footing should be provided for cisterns greater than 1,500 gallons. Reinforcement of the concrete pad is not needed unless the cistern is larger than 10,000 gallons.

All cistern installations must follow manufacturer’s recommendations and [Appendix C-1 of the NC Plumbing Code](#). Please consult the [NC Building Code Sections 1803.5.7 and 1804.1](#) to ensure that the requirements for footing depth, design and placement is correct and will not compromise any adjacent structures. *Make sure to call 811 and locate all utilities prior to siting the cistern.*

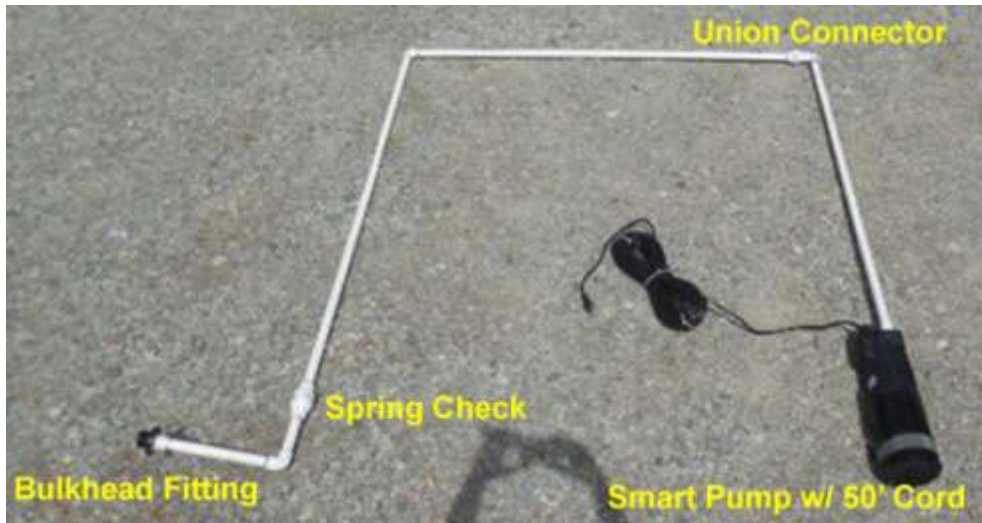
Check the footing to make sure that it is level and at the correct elevation before placing the cistern structure and waterproofing.



**Figure 25-15. Preparing a cistern footing of aggregate (left) and a concrete footing for a cistern exceeding 1,500 gallons (right) (NCSU BAE)**

**25.5.2. Construction Step 2: Place Cistern in its Location and Waterproof**

Any entry into confined space such as a cistern must in accordance with local, state, federal workplace safety requirements under OSHA. If possible, install the passive drawdown, pump, and other components internal to the cistern before placement to avoid the need to enter the system later.



**Figure 25-16. Assemble interior components prior to installing the cistern to avoid a confined space entry (NCSU BAE)**



**Figure 25-17. Installation of a membrane on a 15,000 gallon underground cistern at the Fayetteville Technical Community College NCSU BAE)**

After placement of the cistern, the designer should check the elevations of the drainage components (passive drawdown, pump, fittings, connectors and check valves) to ensure that they are correct. If not, the designer should initiate field changes to ensure the correct volumes are provided.

The next steps are as follows:

- Install collection system components (if this is a new rather than a retrofit site.)
- Ensure that pipe sizing not changed – e.g. downspout sizing can impact the performance
- Clean the collection system prior to connecting to the cistern.
- Ensure that all connections are water-tight.
- Install the distribution system.
- Flush the distribution system piping before attaching to an irrigation system or other components that may be damaged by sediment or debris in the line.



Figure 25-18. Ensure the connections are water-tight. (NCSU BAE)

### 25.5.3. Construction Step 3: Fill the Cistern

Gutters should already be installed when a cistern is to be implemented. Place the downspout debris filter so that it can be easily seen and maintained while still allowing for positive drainage to the tank. There should be approximately 2-3 inches of clearance between the downspout opening and the debris filter to allow for easy removal of debris and leaves. The downspout can be cut with a hack saw, or by another method that will produce a smooth, straight edge.

The debris filter should be mounted on the wall and a pipe should be attached to the bottom of the filter to convey water from the filter to the tank (Figure 25-19a). Again, be sure the pipe is at least as big as the existing gutter downspout. A rubber gasket should be used where the pipe enters the cistern to prevent leaking and ensure a tight fit (Figure 25-19b). These gaskets come in multiple sizes and can be purchased from most cistern vendors.

First flush diverters are used in some cases. They may be needed on systems that do not employ complex debris filters (i.e. vortex filters), or on systems that have a lot of overhanging or nearby vegetation (especially pine trees). Pollen is the primary reason to have them, as this will not be removed by a typical debris filter.





**Figure 25-19. (a) Pipe leading from debris filter to the tank; (b) Rubber gasket used to create leak-free seal when pipe enters the tank. (NCSU-BAE)**

The overflow pipe should be inserted into the tank at a height at or below that of the inflow pipe. A rubber gasket should be used to create a water-tight seal where the overflow pipe enters the tank. The overflow pipe should be positioned such that water is directed away from the tank and any building foundations. Ideally, the overflow water should be piped or diverted to a BMP such as a rain garden. It is not necessary for the overflow piping to be leak-proof (i.e. HDPE pipe may be used in lieu of PVC); however, it is necessary to use PVC pipe when first exiting the tank due to its size (relative to the gasket) and rigidity.

The last step in the construction process is to plumb any spigots or other distribution apparatus. The extract point may be gravity-fed or controlled by a pump. Pumps should be installed per manufacturer's recommendation. Any exposed piping (i.e. connecting an external pump to the cistern, or connecting a spigot to the pump) must be either buried at least a foot or otherwise insulated to prevent freezing or bursting. It is recommended to include a drain valve at the bottom of the tank to facilitate draining of the cistern for maintenance or winterizing.

RWH systems shall be water tight and the distribution system shall be functioning prior to being considered complete. For underground cisterns, test the cistern for water-tightness per the specifications. As stated in the design steps, the designer must specify the testing procedure for underground cisterns. Also, check with the manufacturer for recommended testing about specific products. If an automated make-up water supply is included, check the programming for the start and stop of the make-up water supply to ensure that it is per design.

#### **25.5.4. Construction Step 4: Install Downstream BMP or vegetated receiving area (if applicable)**

For construction requirements for downstream BMPs, refer to those chapters. For vegetated infiltration area construction, refer to the DIS chapter.

### 25.5.5. Construction Step 5: As-Built Inspection

After installation, an appropriately licensed NC design professional shall perform a final as-built inspection and certification that includes:

- Preparing the as-built plans...
- Inspect the cistern and components for cleanliness
- Check the sizing of the downstream BMP or vegetated infiltration area.
- Check site stabilization
- Confirm that water-tightness testing successfully performed
- Confirm that distribution system testing successfully performed
- Confirm that an air gap is provided if a make-up water supply is provided.

Any deficiencies found during the as-built inspection shall be promptly addressed and corrected.

### 25.6. Maintenance

Maintenance is crucial to RWH system performance. Most notably, the gutters and the debris screen should be checked for leaves and other debris after every major storm event, particularly when a tree canopy is near a roof top. Failure to do so will result in water backing up into gutters and onto roofs due to clogging piping and filters. In-line pipe filters, pump intake filters, and spigot filters should be checked annually to ensure they don't become clogged.

It is critical for first flush diverters to be maintained frequently to work correctly. The drain port must be checked frequently, especially during high pollen times. If the port isn't cleaned out, water will bypass the filter completely (rendering it useless) or, in the winter, the water will freeze and burst the pipe on the filter.

Hose and pipe connections should be checked for leaks, especially after freezing temperatures. The cistern should be checked for stability prior to high-wind events (such as hurricanes or severe thunderstorms). If the cistern is consistently low on stormwater, it may become light and require some sort of anchoring system to keep it in place. The owner of the cistern may want to fill it part way with potable water to prevent wind from tipping the cistern. A list of maintenance activities and their associated frequency is shown in Table 25-11.

If water within the cistern is not used for an extended period of time, it may become stagnant and develop a strong odor. To correct this problem, one should drain the stagnant water out of the cistern and add 2 fluid ounces (1/4 cup) of bleach to the tank for every 1,000 gallons of storage. **Be sure to allow the tank to fill up prior to using water;** otherwise the bleach will not be diluted enough to safely use the water. Debris filters are often not fine enough to prevent pollen from entering the tank. While this is generally not problematic, some people find pollen can also create an unpleasant odor. To correct this, add bleach as described above.

The designer and owner must also be aware that the use of RWH systems for stormwater credit requires that these uses must continue. If the non-potable water demand ceases because of a change to the site, the local government and/or NCDENR will require that an alternative non-potable water use may be found or that a properly designed BMP treatment system be installed on site to replace the RWH system.



**Figure 25-20. Pumps need to be pulled periodically for cleaning and preventive maintenance (left). Overhanging vegetation increases the needed frequency of maintenance (right) (NCSU BAE)**



**Figure 25-21. Example of animal damage to cistern and patching of hole. (NCSU BAE)**

**Manuals for Components**

The O&M manual should include manufacturer-specific operation and parts manual for the following components, as applicable:

Pre-treatment (downspout filter, first-flush diverter, etc.)

- Cistern
- Pump
- Valves
- Control System
- Level indicators
- Spigots
- Point-of-Use Treatment (filtration and disinfection)

**Preventive Maintenance Checklists**

The O&M Manual should include preventive maintenance checklists with frequencies that compile the recommendations from the manufacturers of the various system components.

**Installer Contact Information**

The O&M Manual should also include information about the construction team:

- General Contractor
- System Integrator (if applicable)

Important maintenance procedures:

- The roof area will be maintained to reduce the debris and sediment load to the system. Excess debris can clog the system and lead to bypass of the design storm, and reduced reuse volume.
- To ensure proper operation as designed, a licensed Professional Engineer, Landscape Architect, or other qualified professional will inspect the system annually.
- The system components will be repaired or replaced whenever they fail to function properly.
- If the outlet is metered, use must be recorded at a minimum of monthly. These records shall be kept on site.

The system will be inspected by the owner/operator **at least monthly and within 24 hours after each rain event**. Records of operation and maintenance will be kept in a known set location and will be available upon request.

Inspection activities shall be performed as follows. Any problems that are found shall be repaired immediately.



**Table 25-11  
Sample Operation and Maintenance Provisions for Water Harvesting Systems**

<b>BMP Element</b>	<b>Potential Problems</b>	<b>Remedy</b>
The entire system	A component of the system is damaged or leaking.	Make any necessary repairs or replace if damage is too large for repair.
	Water is flowing out of the overflow pipe during a design rainfall or smaller event when there has not been another rainfall event during the past five days.	<ol style="list-style-type: none"> <li>1. Check system for clogging and damage. Repair as needed so the design volume is stored properly without discharged during a design storm.</li> <li>2. Check that the pump is operating properly and that the water is actually being used at the volume designed.</li> <li>3. If it is still not operating properly, then consult an expert.</li> </ol>
The captured roof area	Excess debris or sediment is present on the rooftop.	Remove the debris or sediment as soon as possible.
The gutter system	Gutters are clogged, or water is backing up out of the gutter system.	Unclog and remove debris. May need to install gutter screens to prevent future clogging.
	Rooftop runoff is not making it into the gutter system.	Correct the positioning or installation of gutters. Replace if necessary to capture the roof runoff.
The cistern	Sediment accumulation of 5% or more of the design volume.	Remove sediment.
	Algae growth is present inside the cistern.	<ol style="list-style-type: none"> <li>1. Do not allow sunlight to penetrate the cistern.</li> <li>2. Treat the water to remove/prevent algae.</li> </ol>
	Mosquitoes in the cistern.	<ol style="list-style-type: none"> <li>1. Check screens for damage and repair/replace.</li> <li>2. Treat with 'mosquito dunks' if necessary.</li> </ol>
The screens and filters	Debris and/or sediment has accumulated. Screens and filters are clogged.	<ol style="list-style-type: none"> <li>1. Search for the source of the debris/sediment and remedy the problem if possible.</li> <li>2. Clean/clear</li> </ol>

		debris/sediment from screen or filter. Replace if it cannot be cleaned.
The pump	Pump is not operating properly.	1. Check to see if the system is clogged and flush if necessary. 2. If it is still not operating, then consult an expert.
The overflow pipe	Erosion is evident at the overflow discharge point.	Stabilize immediately.
	The overflow pipe is clogged.	Unclog or replace if it cannot be unclogged.
	The outflow pipe is damaged.	Repair or replace the pipe.
The secondary water supply	Not operating properly.	Consult an expert.

### 25.7. Additional Resources

[American Rainwater Catchment Systems Association \(ARCSA\)](#) is a national organization of rainwater harvesting professionals. The organization is focused on the water supply benefits rather than the stormwater benefits of rainwater harvesting.

[Rainwater Harvesting: Guide for Homeowners \(NCSU\)](#)

[EPA Municipal Handbook: Rainwater Harvesting Policies](#)

[N.C. Plumbing Code Appendix C-1](#)

[N.C. Administrative Code](#)

[Georgia Rainwater Harvesting Guidelines](#)

[Texas Manual on Rainwater Harvesting](#)

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